

Bendix Project 2400

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FOR THE MONTH OF NOVEMBER 1965

STUDY TO INVESTIGATE THE EFFECTS OF
IONIZING RADIATION ON TRANSISTOR SURFACES

(Contract NAS8-20135)

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1.0 SUMMARY

Progress for this period consisted of continuing data analysis for the first X-ray test (Test H-1) and performing a second X-ray test (Test H-2). Test H-2 was performed to evaluate a modified X-ray damage removal cycle and to determine the dependence of damage on X-ray rate. Test H-2 included, in addition to Fairchild 2N1613s, two specially treated transistors (one p-n-p and one n-p-n) supplied by Motorola. The main objective of testing these devices was to determine if Motorola's special surface treatments increased radiation tolerance.

A cursory analysis of H-2 data indicated that (a) the modified removal cycle significantly improved recovery, (b) damage apparently was independent of rate, and (c) Motorola's special surface treatments produced no improvement in tolerance to ionizing radiation.

2.0 ANALYSIS OF TEST H-1 DATA

Analysis of Test H-1 data during this period consisted of plotting X-ray induced gain damage for several devices in two forms, $\Delta 1/h_{FE}$ vs I_C and ΔI_b vs V_{be} . These plots enabled identification of three different components in the excess base current produced by X-rays: surface channel current, surface recombination-generation current, and a current component effective at high injection levels, believed to be diffusion current. The channel and recombination-generation currents are identified by their exponential behavior at low current levels where they dominate. Both components vary as $\exp(q V_{be}/kT n)$ where $n \approx 2$ for recombination-generation and $n > 2$ for channel current. Evidence indicating the presence of a diffusion current component was obtained from ΔI_b vs V_{be} plots at high injection levels, where exponential behavior with $n \approx 1$ was observed for some conditions.

The stability of X-ray damage was evaluated by two methods in Test H-1, one purposely and one inadvertently. The first method consisted of performing the $1 \mu A$ h_{FE} measurements at the beginning and end of each h_{FE} measurement cycle by taking data with I_C 's from $1 \mu A$ to $300 mA$. These measurements were then compared to determine the amount of low level damage removed by the electrical stress imposed by the measurement cycle. Damage removal produced by a cycle varied from 0 percent to 10 percent.

The second stability test was conducted inadvertently when irradiated devices were allowed to remain at room temperature without either bias or irradiation for periods of about 18 hours (overnight). This aging period produced considerable damage removal at low levels for some combinations of bias during irradiation. A very good correlation was

obtained between the two methods for evaluating stability. Reverse bias of either junction during irradiation produced the least stable damage, while a forward bias enhanced stability. A combination of a forward biased E-B junction and a reverse biased C-B junction (active) produced different degrees of stability varying with the past irradiation and bias history of each device.

3.0 TEST H-2

The second X-ray test, H-2, was performed during this period to complement the results of H-1 by investigating the recovery cycle effectiveness and to determine the dependence of gain damage on X-ray rate. Two specially processed devices supplied by Motorola* were also included in the test to determine if the special processes affected radiation tolerance.

Three Fairchild 2N1613s with different bias histories were selected from the devices irradiated in Test H-1. H-1 results had indicated that buildup of damage versus dose, after a device had been irradiated and exposed to a recovery cycle, differed from the buildup when the device was new. In an attempt to produce more complete recovery, the devices selected for H-2 were subjected to a modified recovery cycle consisting of: (a) one day of X-ray exposure with a forward bias of 100 mA applied to both the C-B and B-E junctions, (b) a second day with the same bias but no X-rays, and (c) a 270°C bake for several hours with no bias. Following this modified recovery cycle the three devices were irradiated with the same bias conditions as test step 1 or 3 of Test H-1 (one reverse biased C-B, one forward biased B-E plus reverse biased C-B, and one passive). Temperature controlled data were taken at several points during this irradiation to determine the rate of damage buildup versus dose. After sufficient irradiation had been applied to cause saturation of the damage level, the X-ray rate was decreased from approximately 3.8×10^5 r/hr to 1.3×10^5 r/hr to determine the effect of a lower rate on the ultimate damage level.

Results of this segment of the test are summarized below:

1. The modified recovery cycle produced damage buildup which more closely simulated buildup in a new device than it simulated the buildup obtained after the recovery cycle used in H-1.

* These devices were supplied by K. D. Kang of Motorola Semiconductor Products Division for evaluation in ionizing radiation.

2. The reduction of rate had little or no effect on the ultimate damage level, producing only a small perturbation. The damage eventually settled out at the level expected without rate change.
3. ΔI_b vs V_{be} plots for the device with a reverse biased C-B junction reflected a large channel component ($n \approx 4$) during the initial period of rapid low level damage buildup. After low level damage had saturated, the channel current disappeared, and low level damage could be attributed to a recombination-generation current ($n \approx 2$). This transition from one type of current to another as a function of dose may be very helpful in understanding the mechanisms causing damage.

The second segment of H-2 consisted of passive irradiation of:
(a) a type 2N3493 p-n-p silicon planar transistor of annular structure specially treated to reduce the effects of ionizing radiation (What the treatment consisted of is not known), (b) a standard type 2N2219A n-p-n silicon planar device, and (c) a type 2N2219A modified by additional glass passivation layers and a metallized layer over the junctions to eliminate fringing fields at the surface. All devices for this segment were supplied by Motorola.

This test was only cursory in nature, and all data have not yet been reduced; however, initial analysis indicates that:

- (a) Both type 2N2219A devices were damaged about equally, and that therefore the special passivation techniques produced no substantial improvement.
- (b) Although damage buildup was somewhat slower for the type 2N3493 device, the damage levels reached were similar to those observed for other devices. It is difficult to compare this p-n-p device with the previously tested devices, which were all n-p-n types. The implication that the special passivation techniques did not produce substantial improvements has not yet been assessed.

4.0 WORK PLANS FOR DECEMBER

Work planned for the next period includes continuing the analysis of data from Tests H-1 and H-2 and additional exploratory tests to (a) develop a more effective and practical recovery cycle which would make component screening feasible, and (b) obtain more information on damage components in an attempt to formulate a consistent damage model for all bias conditions.